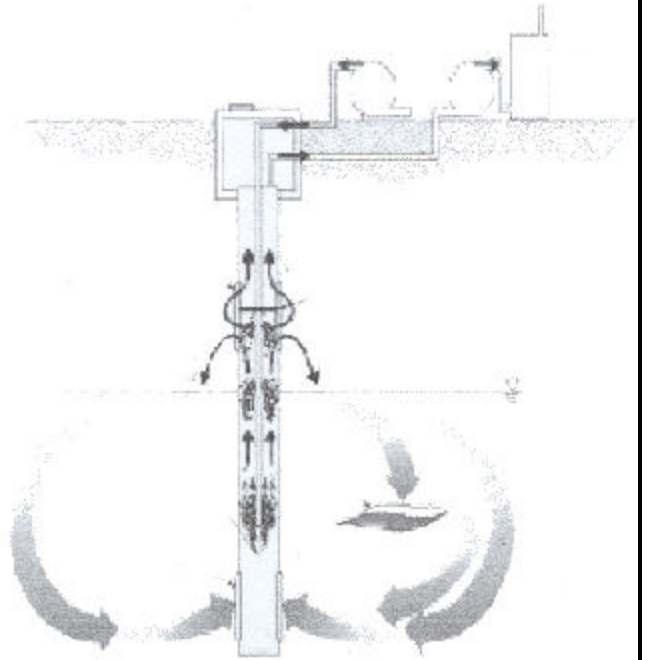


NoVOCs™ Technology Evaluation Report



Appendix C Hydrogeological Report



**HYDROGEOLOGICAL INVESTIGATION OF THE
AQUIFER TREATED BY THE NoVOCsTM SYSTEM**

**NAVAL AIR STATION NORTH ISLAND
SAN DIEGO, CALIFORNIA**

Prepared For

**U.S. Environmental Protection Agency
National Risk Management Research Laboratory
Superfund Innovative Technology Evaluation Program
Cincinnati, Ohio**

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ACRONYMS AND ABBREVIATIONS

bgs	Below ground surface
cm/sec	Centimeters per second
CPT	Cone penetrometer test
DCA	Dichloroethane
DCE	Dichloroethene
DFT	Dipole flow test
DNAPL	Dense nonaqueous phase liquid
Eh	Reduction/oxidation potential
EPA	U. S. Environmental Protection Agency
ft/day	Feet per day
ft/ft	Feet per foot
ft ² /day	Square feet per day
gpm	Gallons per minute
gpm/ft	Gallons per minute per foot
g/cm ³	Grams per cubic centimeter
IR	Installation Restoration
MACTEC	MACTEC Inc.
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
MLLW	Mean lower low water
mv	Millivolts
NAS	Naval Air Station
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric turbidity units
ORD	Office of Research and Development
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear aromatic hydrocarbon
PCE	Tetrachloroethene
psi	Pounds per square inch
PVC	Polyvinyl chloride
scfm	Standard cubic feet per minute
SITE	Superfund Innovative Technology Evaluation
SVOC	Semivolatile organic compound
1,1-TCA	1,1-Trichloroethane
TDS	Total Dissolved Solids
TCE	Trichloroethene

ACRONYMS AND ABBREVIATIONS (continued)

Tetra Tech	Tetra Tech EM Inc.
VOC	Volatile organic compound
Fmhos/cm	Micromhos per centimeter

EXECUTIVE SUMMARY

In support of the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program, Tetra Tech EM Inc. (Tetra Tech) is evaluating the MACTEC Inc. (MACTEC) NoVOCsTM in-well volatile organic compound (VOC) stripping system at Installation Restoration (IR) Site 9 at Naval Air Station (NAS) North Island in San Diego, California. The NoVOCsTM system is a patented recirculating well that is designed for the in situ remediation of groundwater contaminated by VOCs.

In April 1998, the Navy initiated operation of the NoVOCsTM system. By June 1998, the pumping rate had been reduced from the design rate of 25 gallons per minute (gpm) to approximately 5 gpm because not all water pumped at higher rates could be injected into the aquifer. The NoVOCsTM system was shut down on June 19, 1998, to evaluate the cause of the problem. Suspected causes for the poor injection performance included (1) biofouling or scaling of the screen intervals and formation near the NoVOCsTM system, (2) design problems with the NoVOCsTM well, in particular the sizing of the recharge screen, and (3) possible differences in hydraulic characteristics between the upper and lower portions of the aquifer.

EPA directed Tetra Tech to conduct the hydrogeological study at the demonstration site to provide information on the recharge capacity of the NoVOCsTM system and the hydraulic characteristics of the aquifer in the vicinity of the NoVOCsTM system. The groundwater study included: (1) a tidal influence study to evaluate natural variations in water level at the site due to tides in San Diego Bay, and (2) a series of groundwater pumping tests in the shallow and deep portions of the aquifer, including step drawdown tests, a 32-hour constant pumping rate test, an injection test, and a dipole flow test to evaluate the aquifer characteristics in the vicinity of the NoVOCsTM system.

The hydrogeological investigation of the aquifer treated by the NoVOCsTM system has yielded valuable information regarding the hydraulic characteristics of the aquifer, pumping and injection capacities of the NoVOCsTM well, and defects in the NoVOCsTM well. The conclusions of the investigation are as follows:

- 1) The tested aquifer is in good hydraulic communication with San Diego Bay. Groundwater levels at different depths within the aquifer are all influenced by tidal fluctuations in San Diego Bay. The tidal influence of the aquifer is demonstrated by the drawdown data collected from the observation wells during the constant discharge pumping test of the NoVOCsTM well.

- 2) The groundwater levels must be corrected for tidal effects to allow the calculation of aquifer parameters and mean groundwater elevations. In addition, the mean groundwater elevations must be corrected for density effects to allow determination of groundwater flow patterns. After tidal and density corrections, the mean equivalent fresh water head contour maps were generated.
- 3) The aquifer hydraulic tests show that the upper and lower aquifer zones are in good hydraulic communication. Drawdown responses were observed in both aquifer zones during the constant discharge pumping test in the upper aquifer zone and the step-drawdown tests in the upper and lower aquifer zones.
- 4) Groundwater generally flows to the west or northwest in both of the upper and lower aquifer zones. The horizontal hydraulic gradient in both aquifer zones is relatively flat, ranging from 0.005 to 0.01.
- 5) Two methods were developed for tidal correction of groundwater drawdown data obtained during the constant discharge pumping test. The methods involve using the tidal influence study data collected in April 1998 to calculate the tidal efficiency and time lag for each of the observation wells. The estimated tidal efficiency ranges from 0.05 to 0.1 in different tidal cycles at different wells; and time lags range from 46 to 96 minutes.
- 6) Observed drawdown data collected during the constant discharge pumping test were corrected using the two new tidal correction methods. The corrected drawdown (that is, drawdown data with the tidal effects removed) using both methods correlates well with each other and reflects typical pumping test responses. The corrected drawdown matches reasonably well with Neuman type curves for the aquifer parameter estimation.
- 7) The aquifer hydraulic parameters were estimated based on the tidally corrected groundwater drawdown data for the constant discharge pumping test. The average hydraulic conductivity was estimated as 29 feet per day (ft/day) or 0.01 centimeters per second (cm/sec). The average aquifer storativity and specific yield are 0.004 and 0.07, respectively. The average ratio of horizontal to vertical hydraulic conductivity is estimated at 5.7.
- 8) Specific capacity and efficiency of the NoVOCsTM well were estimated based on the step-drawdown tests and water injection test conducted at the NoVOCsTM well. The calculated average specific capacities are 1.48 gallons per minute per foot (gpm/ft) for the upper screened interval during pumping, 1.50 gpm/ft during injection, and 3.22 gpm/ft for the lower screened interval during pumping. The calculated average well efficiencies are 82 percent for the upper screened interval during pumping, 97 percent during injection, and 91 percent for the lower screened interval during pumping. The 97-percent well efficiency for the upper screened injection is for injection of clean tap water.
- 9) The radius of influence, as defined as the distance from the pumping well to an observation well at which drawdown can be positively identified (0.01 feet), was at least 100 feet during the constant discharge pumping test with a pumping rate of 20 gallons per minute (gpm).
- 10) No positive (recharge) or negative (flow barrier) boundaries are evident from the constant discharge pumping test data.

- 11)** The injection test results show that the maximum flow of clean tap water that can be injected through the upper screen of the NoVOCs™ well is 25 gpm. At that injection rate, the water level will rise 17 feet and reach the ground surface.
- 12)** The video survey of the NoVOCs™ well revealed a manufacturing defect in the upper well screen. The screen slots are unevenly cut, and about 30 percent of the slots do not completely penetrate the PVC casing. This defect affects the well efficiency of the upper screened interval and may reduce the available water level rise in the NoVOCs™ well during recharge to the aquifer through the upper screen.
- 13)** The video survey also revealed significant fouling of the NoVOCs™ well screens by iron precipitation and microbiological growth. Such fouling may impair the performance of the NoVOCs™ system by obstructing the well screen and filter pack.
- 14)** The findings of the aquifer tests and tidal study of the aquifer treated by the NoVOCs™ system indicate that the aquifer hydraulic conditions are suitable for application of the NoVOCs™ technology. The NoVOCs™ well as designed should be able to extract and inject a flow rate of 20 gpm based on the aquifer hydraulic characteristics.

1.0 INTRODUCTION

In support of the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program, Tetra Tech EM Inc. (Tetra Tech) is evaluating the MACTEC Inc. (MACTEC) NoVOCsTM in-well volatile organic compound (VOC) stripping system at Installation Restoration (IR) Site 9 at Naval Air Station (NAS) North Island in San Diego, California. The NoVOCsTM system is a patented recirculating well that is designed for the in situ remediation of groundwater contaminated by VOCs. A vicinity map, site location map, and site plan are presented as Figures 1-1, 1-2, and 1-3.

In April 1998, the Navy initiated operation of the NoVOCsTM system. The EPA SITE Program evaluation of the NoVOCsTM system also began in April 1998, and included collection of air and groundwater samples from the NoVOCsTM system and surrounding monitoring points. The evaluation was conducted in accordance with the draft final "Technology Evaluation Plan/Quality Assurance Project Plan for the MACTEC NoVOCsTM Technology Evaluation at NAS North Island" (Tetra Tech 1998). By June 1998, the pumping rate had been reduced from the design rate of 25 gallons per minute (gpm) to approximately 5 gpm because not all water pumped at higher rates could be injected into the aquifer. Based on discussions between the Navy and the technology developer, the system was shut down on June 19, 1998, to evaluate the cause of the poor injection performance. Suspected causes for the poor injection performance included (1) biofouling or scaling of the screen intervals and formation near the NoVOCsTM system, (2) design problems with the NoVOCsTM well, in particular the sizing of the recharge screen, and (3) possible differences in hydraulic characteristic between the upper and lower portions of the aquifer. This report presents the results of a hydrogeological investigation to assess the hydraulic characteristics of the aquifer that may affect the NoVOCsTM system performance.

EPA directed Tetra Tech to conduct the hydrogeological study at the demonstration site to obtain information on the recharge capacity of the NoVOCsTM system and the aquifer hydraulic characteristics in the vicinity of the NoVOCsTM system. The hydrogeological study included: (1) a tidal influence study to evaluate natural variations in water level at the site due to tides in San Diego Bay, and (2) a series of aquifer hydraulic tests in the shallow and deep portions of the aquifer, including step drawdown tests, a 32-hour constant discharge pumping test, an injection test, and a dipole flow test to evaluate the aquifer characteristics in the vicinity of the NoVOCsTM system.

This report presents background information on the NoVOCs™ system and IR Site 9, documents the field methods and procedures implemented during the groundwater study, presents the study results, discusses the data analysis and interpretation, and presents conclusions based on the information obtained. The remainder of this section presents information on the EPA SITE program and the hydrogeological study objectives.

1.1 SITE PROGRAM

SITE was established by EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) in response to the Superfund Amendments and Reauthorization Act of 1986. The SITE program was established to accelerate the development, evaluation, and use of innovative technologies to remediate hazardous waste sites. The evaluation portion of the SITE program focuses on technologies in the pilot- or full-scale development stage. The evaluations are intended to collect performance data of known quality. In support of this portion of the program, a series of aquifer tests were conducted to assist in evaluating the NoVOCs™ system by providing a greater understanding of the site hydrogeology.

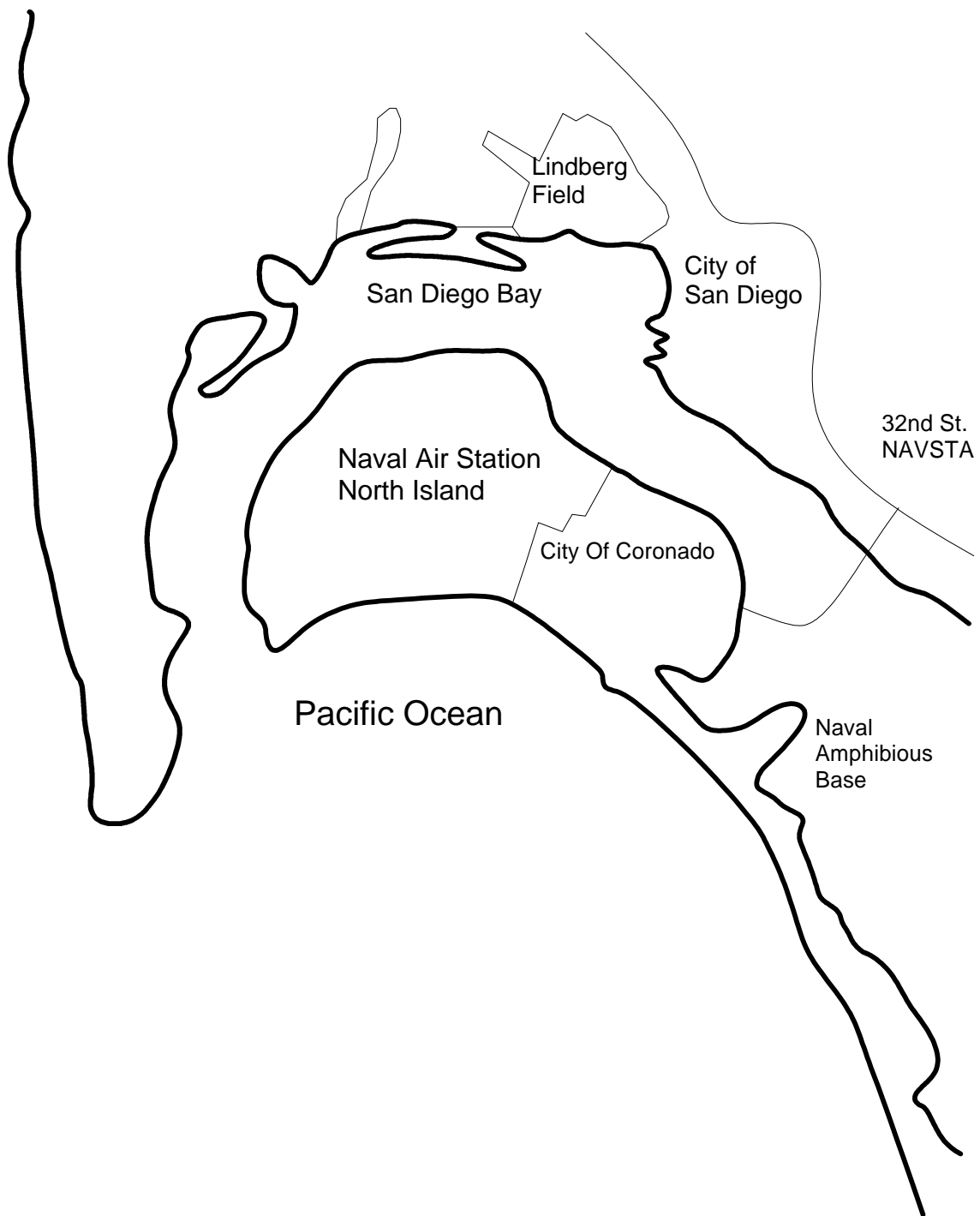
1.2 PROJECT OBJECTIVES

The overall objective of the groundwater study was to assess hydraulic characteristics of the aquifer in the vicinity of the NoVOCs™ system at the demonstration site. In support of this objective, the specific objectives of the groundwater study were to: (1) document groundwater elevation change (water level) in selected wells due to tidal influence, and (2) conduct a series of aquifer hydraulic tests to assess hydrogeologic conditions in the vicinity of the NoVOCs™ system.

Aquifer hydraulic tests of the NoVOCs™ well (IW-01) were conducted to estimate or assess the following:

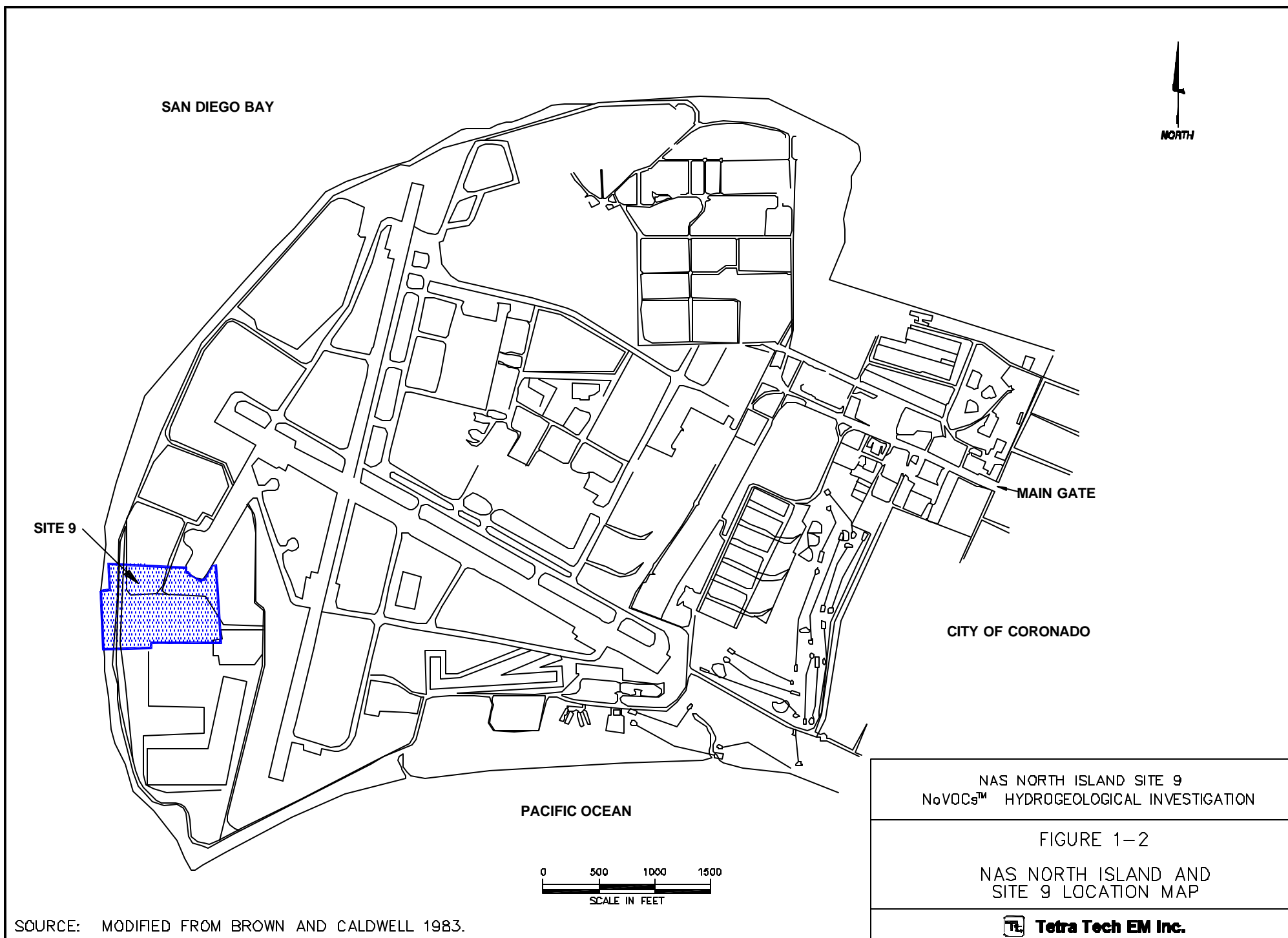
- Well efficiencies of the two screened intervals of the NoVOCs™ well: the outer casing is screened at 43 to 47 feet below ground surface (bgs) (-21.3 to -25.3 feet relative to mean lower low water [MLLW]) and 72 to 78 feet bgs (-50.3 to -56.3 feet MLLW).
- Hydraulic parameters of the upper and lower portions of the aquifer, including estimation of hydraulic conductivity, transmissivity, storativity, and aquifer anisotropy.
- The radius of influence established during pumping.

- The presence of hydraulic barriers that may affect hydraulic communication between the upper and lower zones of the aquifer.

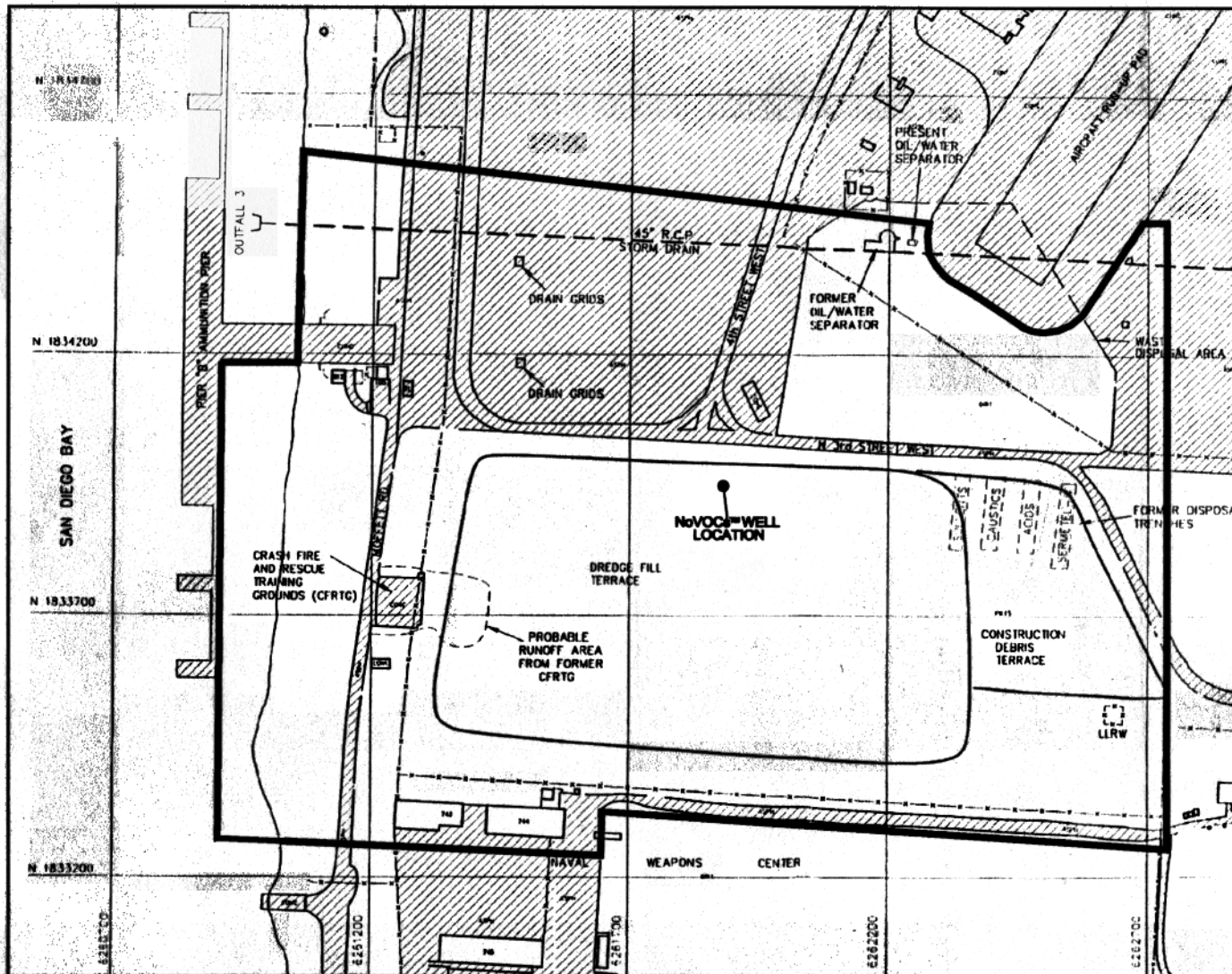


NAS NORTH ISLAND SITE 9
NoVOCs™ TECHNOLOGY EVALUATION

**FIGURE 1-1
VICINITY MAP**



SOURCE: MODIFIED FROM BROWN AND CALDWELL 1983.



LEGEND

- FENCE
- ROAD AND STREET
- BUILDING
- PAVEMENT (CONCRETE OR ASPHALT)
- TERRACE BORDERS
- LLRW
- STORM DRAIN
- SITE 9 BOUNDARY

NOTES:

1. BASE MAP ADAPTED FROM PHOTGRAMMETRY BY BECHTEL NATIONAL, INC., 1994.
2. ELEVATION DATUM IS MEAN LOWER LOW WATER.
3. COORDINATES ARE IN THE CALIFORNIA COORDINATE SYSTEM (1983) ZONE 6 BASED ON THE NORTH AMERICAN DATUM (1983).



NAS NORTH ISLAND SITE 9
NoVOCSTM HYDROGEOLOGICAL INVESTIGATION

FIGURE 1-3

SITE 9 CHEMICAL WASTE DISPOSAL AREAS

2.0 BACKGROUND

This section describes the NoVOCsTM system and the associated groundwater monitoring system at NAS North Island. This section also provides information on site conditions, including site history, topography, geology, hydrogeology, and soil and groundwater contamination. In addition, this section identifies the locations and describes the construction of wells installed to investigate the hydrogeology of the site.

2.1 THE NoVOCsTM SYSTEM

This section provides a general description of the NoVOCsTM system at NAS North Island and describes the groundwater monitoring system for evaluating the NoVOCsTM system performance.

2.1.1 General Description

The NoVOCsTM system is a patented in-well stripping process (U.S. Patent No. 5,180,503) for in situ removal of VOCs from groundwater. A diagram of the treatment process is shown in Figure 2-1. In this process, air injected into a specially designed well simultaneously creates an air-lift pump and an in situ stripping reactor to circulate and remediate groundwater (EG&GE 1996).

The NoVOCsTM system consists of a well casing installed in the contaminated saturated zone, with two screened intervals below the water table and an air injection line extending into the groundwater within the well. Contaminated groundwater enters the well through the lower screen and is pumped upward within the well by pressurized air supplied through the air injection line, creating an air-lift pump effect. As the water is air-lifted within the well, dissolved VOCs in the water volatilize into the rising air bubbles and are transported to the upper portion of the well. The treated water rises to a deflector plate and is forced out the upper screen. The treated water is recharged to the aquifer, and the stripped VOC vapors are removed from the subsurface by a vacuum applied to the upper well casing (EG&GE 1996). The stripped vapors then are treated by the Thermatrix flameless oxidation process. The equipment used to operate the NoVOCsTM system, including blowers, control panel, and air temperature, pressure, and flow rate gauges is housed in an on-site control trailer.

2.1.2 NoVOCsTM Monitoring System at NAS North Island

At NAS North Island, one NoVOCsTM well has been installed to remediate a portion of the aquifer downgradient of a contaminant source area. Assuming the designed pumping rate of 25 to 30 gpm and a total air flow rate of 120 standard cubic feet per minute (scfm), the radius of influence of the NoVOCsTM well for this site is predicted to be at least 90 feet (EG&GE 1997). To evaluate the accuracy of this prediction and to obtain information on the horizontal and vertical extent of the NoVOCsTM treatment cell and assess changes in contaminant concentrations within the treatment cell, two ½-inch outer diameter piezometers (PZ-01 and PZ-02) and 10 2-inch outer diameter groundwater observation wells (MW-45 through MW-54) were installed.

Figure 2-2 shows a plan view of the location of the NoVOCsTM well and observation wells. Figure 2-3 shows a generalized cross-section of the NoVOCsTM well, piezometers, and observation wells. The two piezometers were installed within the sand pack of the NoVOCsTM well: one adjacent to the NoVOCsTM recharge screen (PZ-01), and one adjacent to the NoVOCsTM intake screen (PZ-02). The natural groundwater flow direction across the site is generally to the west. Seven cross-gradient observation wells were installed at four distances from the NoVOCsTM well, as follows: a cluster of three wells 30 feet from the NoVOCsTM well (observation wells MW-45, MW-46, and MW-47), a well pair 60 feet from the NoVOCsTM well (observation wells MW-48 and MW-49), and single observation wells 90 and 105 feet from the NoVOCsTM well (observation wells MW-50 and MW-51). Two downgradient observation wells (MW-52 and MW-53) were installed as a pair approximately 100 feet from the NoVOCsTM well, and a single observation well (MW-54) was also installed 100 feet upgradient of the NoVOCsTM well. Each observation well was screened at one of the following three intervals: at the top of the treatment zone (between approximately 41 and 47 feet bgs [-19.1 to -25.0 feet MLLW]), in the middle of the treatment zone (between approximately 49 and 62 feet bgs [-35.1 to -40.4 feet MLLW]), and at the bottom of the treatment zone (between approximately 67 and 78 feet bgs [-43.6 to -58.0 feet MLLW]). A summary of well screen intervals for the individual wells is presented in Table 2-1.

2.2 SITE HISTORY

NAS North Island is the largest naval aviation complex on the West Coast and is home to two aircraft carriers and the Third Fleet flagship, USS Coronado. NAS North Island is located at the northern end of the peninsula that forms San Diego Bay and is bordered by the City of Coronado to the east, the Pacific Ocean to the south, and San Diego Bay to the north and west (Figure 1-1). The 2,806-acre complex,

officially commissioned in 1917, provides aviation support services to the fleet, aircraft maintenance, airfield operations, pierside services, and logistics. The mission of NAS North Island is to maintain and operate facilities and to provide services and materiel that support operation of aviation activities and units of the Operating Forces of the Navy, as well as other units as designated by the Chief of Naval Operations.

Past hazardous waste disposal practices at NAS North Island have resulted in soil and groundwater contamination. The Navy has undertaken investigations to determine the extent of contamination and possible cleanup methods as part of the IR Program. Under the IR Program, 14 contaminated areas have been designated IR sites, one of which is Site 9 (Figure 1-2).

Site 9, the 40-acre former chemical waste disposal area, is located on the western end of NAS North Island. Site 9 operated from the 1940s to the mid-1970s and consisted of three major waste disposal areas: a shallow pit used for disposal of liquid wastes (located within the waste disposal area shown in Figure 1-3); four parallel trenches each containing different types of wastes (solvents, caustics, acids, and semisynthetics consisting of ceramic and metallic compounds); and a large unimproved area used for burying drums containing unidentified chemical wastes located south of the NoVOCsTM well. An estimated 32 million gallons of waste were disposed of at Site 9 over its 30 years of operation (Jacobs 1995a).

Contamination from these disposal areas has migrated to the underlying groundwater. Although there is no official history of chemical disposal for most of Site 9 outside of the three disposal areas, groundwater contamination is widespread throughout the site. Elevated levels of chlorinated solvents and their breakdown products, as well as petroleum hydrocarbons and metals, are present in groundwater at Site 9. Based on the high dissolved concentrations of chlorinated solvent compounds, the presence of dense nonaqueous phase liquids (DNAPL) in the subsurface is suspected.

The Navy selected a location immediately south of the intersection of 4th Street West and North 3rd Street West to install the NoVOCsTM system (Figure 1-3). Cone penetrometer test (CPT) boreholes advanced at the proposed NoVOCsTM location provided additional characterization of subsurface lithology and confirmed that significant groundwater contamination was present (Bechtel 1998).

2.3 SITE TOPOGRAPHY

The topography of the northern half of Site 9 is relatively flat with an elevation of approximately 13 feet above MLLW. It has virtually no relief and is covered by asphalt paving. The southern half of the site is unpaved, and is almost entirely covered by a terrace composed of hydraulic dredge spoils. The terrace has an elevation of approximately 23 feet above MLLW along its north face and slopes gently southward to approximately 18 feet above MLLW (Jacobs 1994). Topographic elevations and surface features are shown in Figure 2-4. The NoVOCsTM well is located on the terrace at a surface elevation of approximately 22 to 23 feet above MLLW.

2.4 REGIONAL AND SITE GEOLOGY

This section discusses the regional and site geology for Site 9.

2.4.1 Regional Geology

NAS North Island is situated in the coastal portion of the Peninsular Range Geologic Province. This region is underlain by a basement complex of late Cretaceous undifferentiated igneous rocks of the Southern California Batholith and Jurassic prebatholithic metavolcanic rocks. The basement complex is nonconformably overlain by a sedimentary succession of marine and nonmarine rocks that were deposited within the San Diego embayment. These rocks range in age from Late Cretaceous to Recent. The most abundant deposits of the embayment are gently folded and faulted Eocene marine, lagoonal, and nonmarine rocks that thin eastward and trend northwest.

2.4.2 Site Geology

Site 9 is underlain by artificial fill to a depth of approximately 15 feet bgs in the vicinity of the NoVOCsTM well. The artificial fill in this area varies in thickness. The terrace is composed of hydraulic fill derived from dredging the San Diego Bay and consists of fine-grained, loose sand. In addition, in the immediate vicinity of the site, the former Whaler's Bight, a shallow lagoon formerly present at the western edge of North Island, was filled with sediments during the early part of the twentieth century. Below the fill material is the Bay Point Formation, a poorly consolidated, fine- and medium-grained fossiliferous sandstone (Kennedy 1975).

The depositional environment of the site was lagoonal and shallow marine. Sediment accumulated on the southern portion of North Island generally from northward transport of sediment along the shore. As described below, most of the uppermost sediments at the site are composed of fine-grained sand, with varying amounts of silt and medium-grained sand. Two thin silt and clay layers are present in the subsurface at the site and are likely to be continuous in the vicinity of the site, based on observations in the numerous borings and wells installed at the site (Bechtel 1998).

The first fine-grained layer is a thin (2 to 5 feet thick) clay, silt, and clayey sand layer designated as “A clay/silt” (Jacobs 1994). A clay/silt occurs at approximately 35 to 40 feet bgs and is present beneath Site 9 (Jacobs 1994). Recent investigations by Bechtel have indicated that the A clay/silt is continuous from the proposed NoVOCs™ well locations west to the shoreline wells. Beneath the unconsolidated sediments is a sandstone layer at approximately 90 feet bgs. The second layer is the B clay, located approximately 105 feet bgs that also appears to be continuous in the vicinity of the site. The location of a geologic cross-section is shown in Figure 2-5, and the cross-section depicting the subsurface geology of the site is shown in Figure 2-6.

Boring S9-SB-34 located near the NoVOCs™ well encountered mostly sand and silty sand. The A clay/silt was encountered at 35.5 feet bgs, dense sands were encountered between 60 and 61 feet bgs and 65 to 67.5 feet bgs, and a thin cemented sandstone layer was encountered at 79 feet bgs. In addition, the sand fractions of the sands and silty sands ranged from very fine- to coarse-grained and contained various quantities of shell fragments. The log for boring S9-SB-34 is provided in Appendix A.

2.5 SITE HYDROGEOLOGY

The generally accepted hydrogeologic model for islands and peninsulas surrounded by salt water is a lens-shaped body of fresh water resting isostatically atop salt water because of density differences. At Site 9, groundwater occurs at approximately 8 feet bgs (5 feet above MLLW). The upper 110 feet of the saturated zone contains an unconfined aquifer with a thin (5 to 20 feet), discontinuous fresh water lens, a brackish mixing zone (30 to 100 feet), and a seawater wedge intruding inland. Values for some of the hydrogeological parameters of the site are as follows (Jacobs 1995b):

- Hydraulic Gradient: 0.0008 foot per foot (ft/ft) over most of the site, but steepens near the shoreline to 0.006 ft/ft
- Transmissivity: 1,195 square feet per day (ft²/day)

- Specific yield: 3.2×10^{-1} (dimensionless)
- Hydraulic Conductivity: 12 feet per day (ft/day) or 4.2×10^{-3} centimeters per second (cm/sec)
- Effective Porosity: 0.25 (dimensionless)

In general, the hydraulic gradient is toward the west, varying between southwest and northwest. The groundwater is tidally influenced.

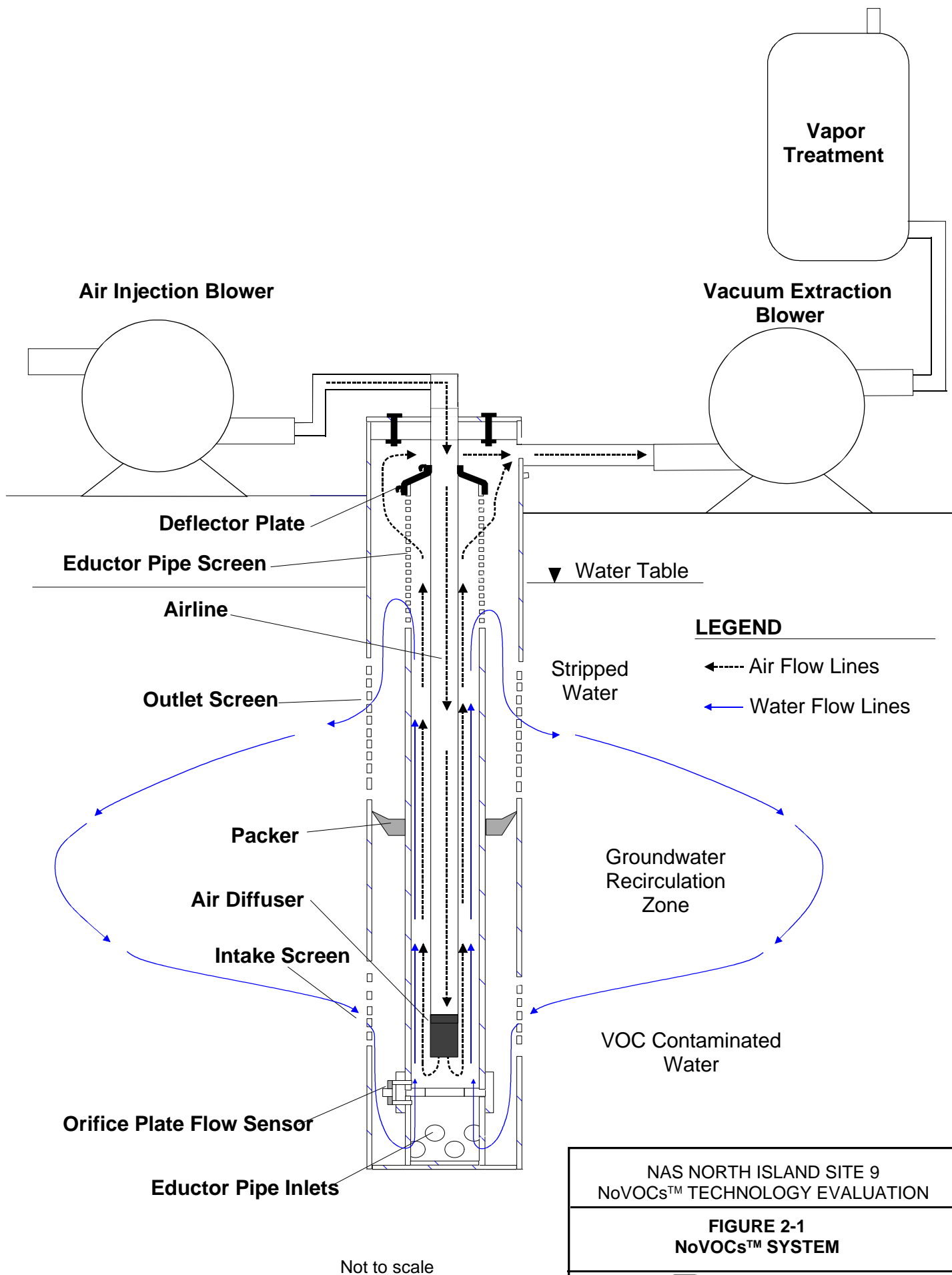
The distribution of groundwater contamination suggests that the general flow of groundwater is toward the west. Contaminants associated with the site have been detected in pore water of San Diego Bay, west of Site 9 (SPARWAR Systems Center 1998). A survey of pore water concentrations of VOCs was conducted in the spring of 1998 in the upper 5 feet of sediment adjacent to and west of Site 9. The results of the survey documented that VOCs were present in the pore water at depths of approximately 20 to 30 feet below MLLW. The data suggest that contaminants are migrating west from Site 9, at a depth consistent with the A clay/silt layer, and discharging to the bay through pore water interchange with the bay water (Bechtel 1998).

2.6 SOIL AND GROUNDWATER CONTAMINATION

Based on findings from previous investigations at the site (Jacobs 1995a,b), high concentrations of chlorinated solvents, chlorinated solvent breakdown products, petroleum hydrocarbons, and metals are present in the saturated and unsaturated zones. The major contaminants detected in groundwater are chlorinated aliphatic hydrocarbon solvents (tetrachloroethene [PCE], trichloroethene [TCE], and 1,1,1-trichloroethane [1,1,1-TCA]) and their breakdown products (dichloroethane [DCA], dichloroethene [DCE], and vinyl chloride); lower concentrations of aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene); and heavy metals. Because of the high concentrations of chlorinated solvent compounds in groundwater above the B clay, DNAPL occurrences are suspected at several locations beneath Site 9. If present, DNAPL may act as a long-term source of dissolved-phase contamination in the unconfined aquifer.

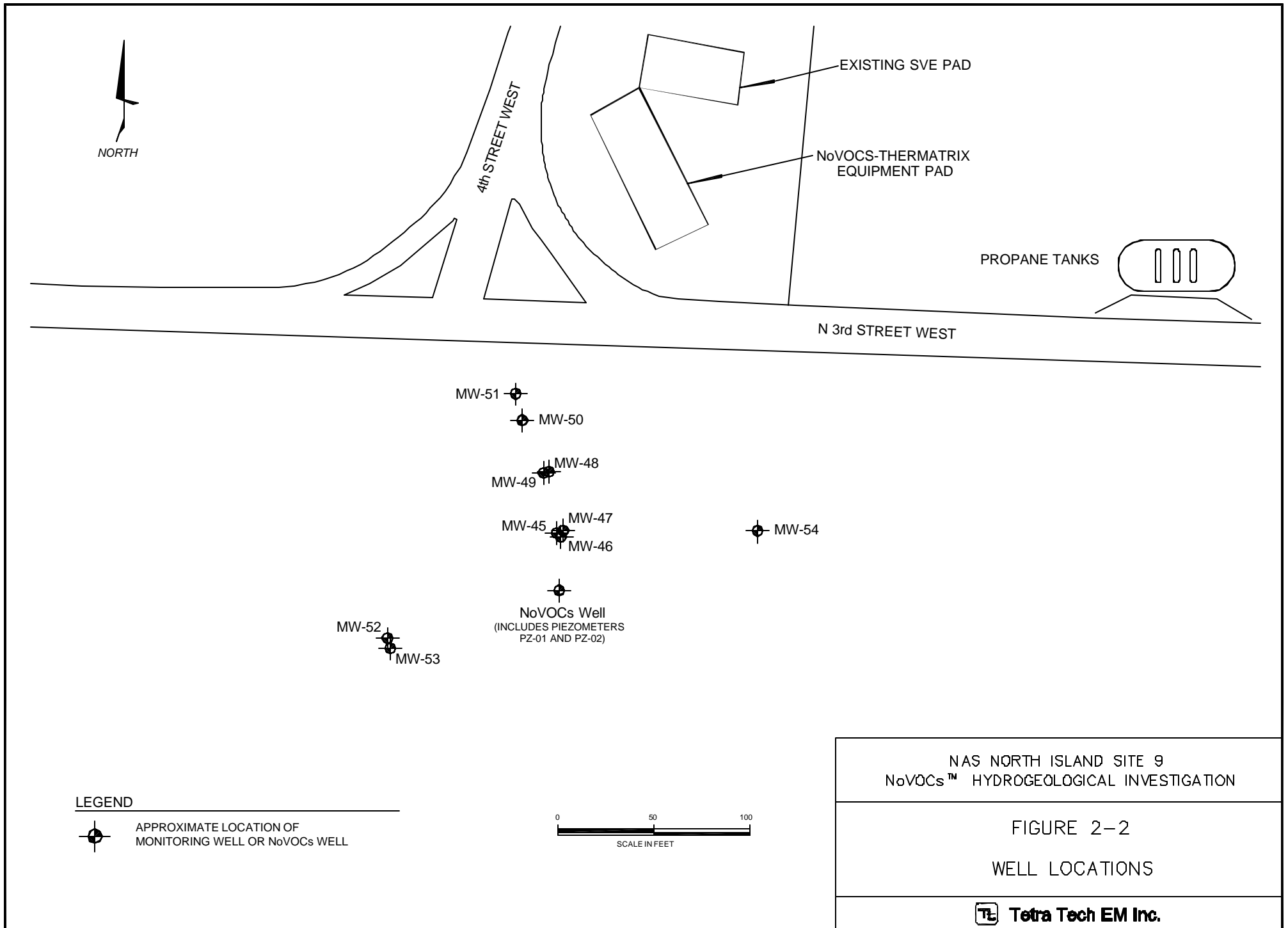
Contaminants in soils consist of heavy metals, VOCs, and semivolatile organic compounds (SVOC). Eighteen priority pollutant VOCs were detected in soil samples with individual compound concentrations of up to 3,600 milligrams per kilogram (mg/kg). Fourteen priority pollutant SVOCs, including

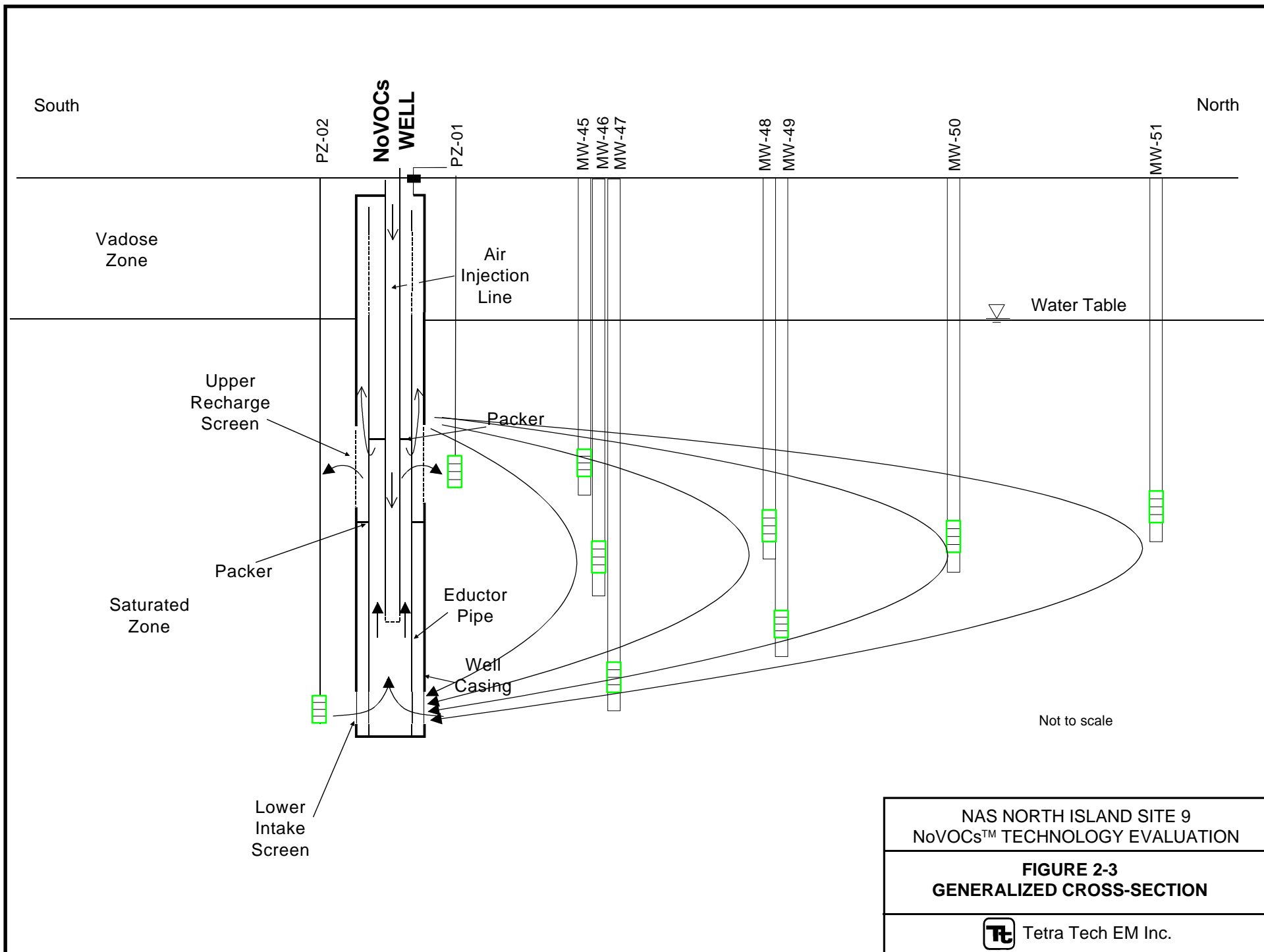
polynuclear aromatic hydrocarbons (PAH), were detected in soil samples with individual compound concentrations up to 1,668 mg/kg. In the former release areas, soils reportedly are virtually saturated with VOCs (Jacobs 1995a). In addition, large quantities of VOCs are believed to have evaporated from saturated soils and groundwater into the vadose zone. Elevated levels of TCE, PCE, and toluene have been detected in soil gas within the vadose zone.

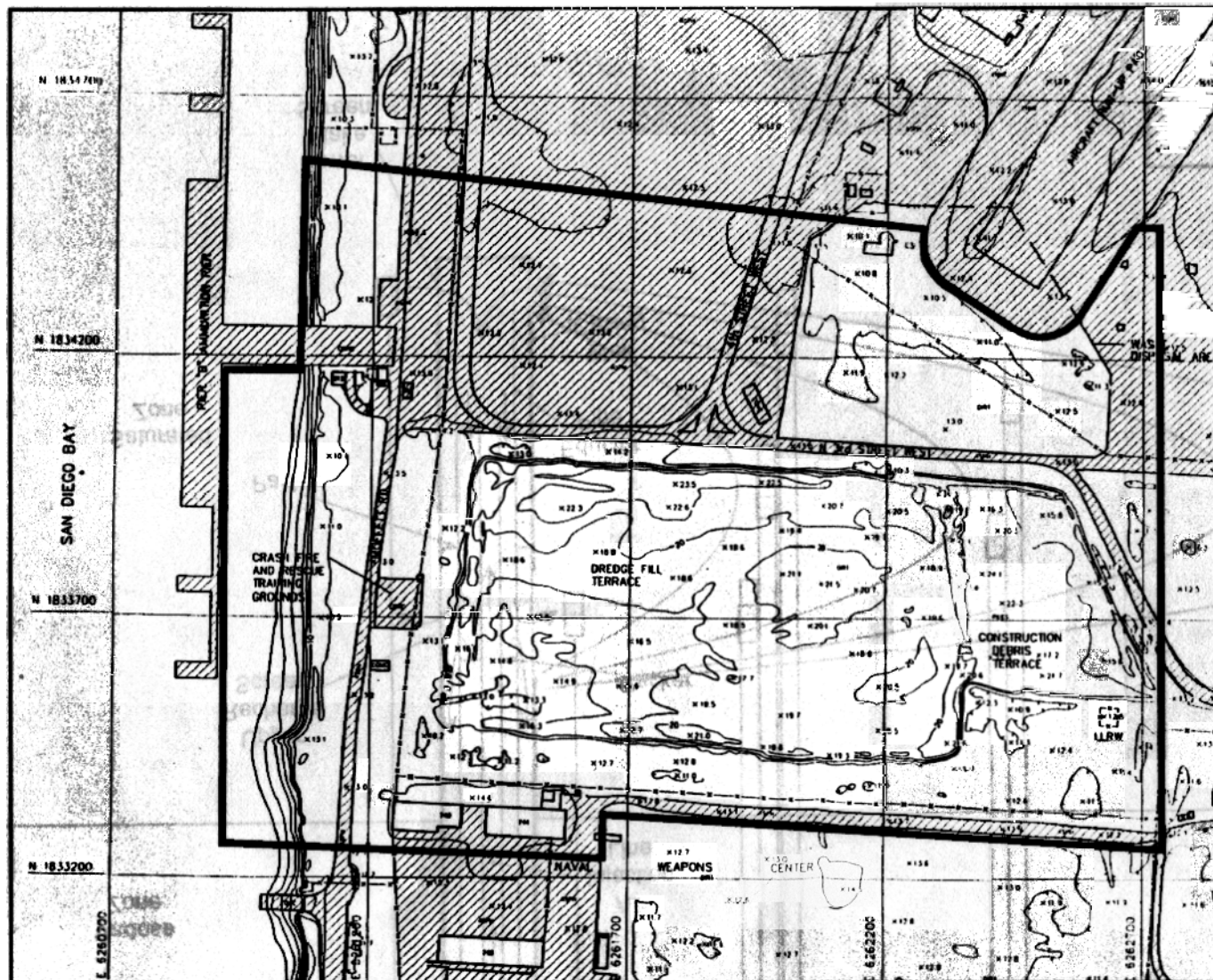


NAS NORTH ISLAND SITE 9
NoVOCs™ TECHNOLOGY EVALUATION

FIGURE 2-1
NoVOCs™ SYSTEM







LEGEND



CONTOUR LINE



FENCE

ROAD AND STREET



BUILDING

X 12.3

SPOT ELEVATION



PAVEMENT (CONCRETE OR ASPHALT)

LLRW

LOW-LEVEL RADIOACTIVE WASTE STORAGE AREA

SITE 9 BOUNDARY

NOTES:

1. BASE MAP ADAPTED FROM PHOTGRAMMETRY BY BECHTEL NATIONAL, INC., 1984.
2. ELEVATION DATUM IS MEAN LOWER LOW WATER.
3. COORDINATES ARE IN THE CALIFORNIA COORDINATE SYSTEM (1983) ZONE 6 BASED ON THE NORTH AMERICAN DATUM (1983).



NAS NORTH ISLAND SITE 9
NoVOCs™ HYDROGEOLOGICAL INVESTIGATION

FIGURE 2-4

SITE 9 TOPOGRAPHIC ELEVATIONS